Classification by Column and Type of the Generalized Distal Radius Die-Punch Fractures

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Research Article

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Abstract

**Background:** There was no three-column classification for generalized distal radius die-punch fractures (GDP) which can involve three-columns. The aim of this study was to investigate the classification by three-column and type of GDP.

**Methods:** 613 patients with GDP accrued from January 2013 to December 2021 were classified by column and fracture type. First, the GDP were separated into single-, double-, or three-column fractures. Second, the intermediate column fractures were categorized into volar, dorsal, split, collapse or mixed type, the radial column fractures were categorized into metaphyseal, articular or mixed type, and the ulnar column fractures were categorized into styloid process or metaphyseal type. Observing the classification results. The intra- and inter-observer consistency between two assessors was analyzed with kappa statistics.

**Results:** There were significant differences in the incidence (12.7%, 68.5% and 18.8%, respectively) and age (39.8, 46.6 and 47.1 years, respectively) for single-, double- and three-column fractures but no significant difference in terms of gender among the three (P>0.05). The mixed, collapse, split, dorsal and volar types were 28.7%, 27.7%, 21.9%, 15.5% and 4.5%, respectively. The metaphyseal, articular surface and mixed types were 35.9%, 33.1% and 31.0%, respectively. The styloid process and metaphyseal types were 81.7% and 18.3%, respectively. Among the cases of volar and dorsal types, the missed diagnosis rate of X-ray was 28.5%. To the last follow-up of 12.2 months (range, 6 to 24 months), the wrist function was evaluated according to the Sarmiento modified Gartland-Werley method, the excellent plus good rate of the single column fractures was 96.2%, significantly higher than that of double- and three-column fractures (80.0% and 83.5%, respectively) (P<0.05). All patients that had poor wrist function were collapse or mixed type intermediate column fractures. The intra-observer kappa coefficient was between 0.810 and 0.861 and the inter-observer kappa coefficient was between 0.830 and 0.876.

**Conclusion:** Different types of GDP have significant differences in terms of injury mechanism, incidence, age and prognosis. Classification by column and type of GDP reflects the features and has important reference value for clinical diagnosis and treatment.

Instruction

Intra-articular fractures of the distal radius account for approximately 5% of all forearm fractures and were the most difficult fractures to handle in clinical orthopaedics [1,2]. In 1962, Scheck initially referred the dorsal articular surface avulsion fracture of the lunate fossa of the distal radius as a die-punch fracture fragment [3]. Later, the articular surface fracture of the lunate fossa resulting from the load transmitting through the lunate was referred to as the distal radius die-punch fractures (DP) [4,5].

DP are specific intra-articular fractures of the distal radius and have been considered an independent fracture disease. Early views believed that the distal radius DP were limited to the articular surface of the lunate fossa, which we refer to as narrowed DP (NDP). Later, accumulating evidence demonstrated that in addition to the articular surface fracture of the lunate fossa, there were also DP involving the distal radial half of the radius or associated with ulnar styloid process fractures [6-8]. Ye Y et al [8] reported that in the distal radius DP a collapsing fracture was more common, not only involving the articular surface fracture of the lunate fossa, but also affecting the radial half of the distal radius, and open reduction and internal fixation plus external fixation were recommended. We refer to such DP involving the distal radial half or/and ulnar styloid process as generalized DP (GDP). However, the International Internal Fixation Organization for Fracture - Arbeitsgemeinschaft für Osteosynthese (AO) does not describe different types of distal radius DP. According to the "three-column theory" of distal radioulna fracture proposed by Rikl and Regazzoni [9] in 1983 (intermediate, radial and ulnar columns), GDP should be referred to as single-column, double-column and three-column fractures, respectively. However, only classifications for NDP [5,10,11] and double-column DP [12] have been reported in the literature; there is no three-column classification for GDP. Fracture classification helps communicate and guide treatment. The purpose of this study was to review the data of patients with GDP in our hospital with respect to classification according to column and typing of the GDP based on the three-column theory, as well as the differences between different types.

Materials And Methods

**Inclusion and exclusion criteria**

Inclusion criteria: (1) the articular surface fracture of the intermediate column of the distal radius resulting from axial loading forces, or the above being the main fracture in conjunction with mild fracture of the radial column or/and the styloid process of the ulna; (2) follow-up duration > 6 months. Exclusion criteria: (1) the open articular surface fracture of the intermediate column of the distal radius resulting from direct violence; (2) age ≤ 15 years old; (3) no CT scans or incomplete imaging data; (4) lost to follow-up.

**General materials**

The study comprised 613 patients with GDP in Wuxi the Ninth People's Hospital, accrued from January 2013 to December 2021, and 56 patients were excluded (inclusion rate 92%). There were 338 (55%) males, 275 (45%) females, with an age range of 16 to 95 years old (average, 45.8 years).
The causes of fractures were as follows: fall injury, 392 (64%); impact injury, 134 (22%); and traffic accident injury, 87 (14%). Conservative treatment was utilized in 227 patients with less fracture displacement, whereas 386 patients with increased fracture displacement were treated surgically. The study was approved by the Institutional Review Board of our hospital (date: May 6, 2021/No. LY-2020015), and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. Signed informed consent to participate in the study was obtained from each patient.

**Classification by column and fracture type**

First of all, it is necessary to determine which column is fractured, and secondly, to determine what type of fracture.

According to the three-column theory and those parts affected by the fractures, the GDP were initially separated into single-, double-, or three-column fractures. A fracture that limited to the articular surface of the lunate fossa was defined as an intermediate column fracture; A fracture line that extended to the radial cortical border or articular surface of the radial column was defined as a radial column fracture; A fracture that occurred in the ulnar styloid process or the metaphyseal of the ulnar was defined as an ulnar column fracture. Figure 1.

The intermediate column fractures were categorized into 5 types: volar, dorsal, split, collapse and mixed types; the radial column fractures were categorized into 3 types: metaphyseal, articular and mixed types; and the ulnar column fractures were categorized into 2 types: styloid process and metaphyseal types. The mixed type of the intermediate column fractures was defined as having characteristics of both split and collapse types. Metaphyseal type of the radial column fractures was defined as a fracture line extending to the radial cortical border (RCB) of the radial column, and the articular type was defined as a fracture line extending to the articular surface of the radial column. Figures 2–9.

**Inter- and intra-observer agreement measurement**

One senior radiologist and one junior radiologist were selected and trained with the above classification methods and classified 100 cases of GDP patients independently. A second classification was conducted 3 months later. When discrepancies occurred between the two observers, the result was determined by the senior radiologist.

**Fracture description method**

The capital letters A, B and C were used to represent the intermediate column, radial column and ulnar column respectively; Arabic numerals 1–5 were used to represent the different types. Therefore, the volar, dorsal, split, collapsed and mixed types of the intermediate column fractures were recorded as A1, A2, A3, A4 and A5, respectively. The metaphyseal, articular and mixed types of radial column fractures were recorded as B1, B2 and B3, respectively, and the styloid process and metaphyseal types of the ulnar column fractures were recorded as C1 and C2, respectively. See Fig. 2–9.

**Statistical methods**

Statistical analysis was performed with SPSS 16.0 statistical package to compare the differences in incidence, gender, age, treatment methods and functional recovery among the three. One-way ANOVA analysis was performed for measurement data, and χ² test was performed for count data. Cohen's kappa coefficient was used to measure the inter- and intra-observer agreement. P < 0.05 was considered to have significant differences.

**Results**

There were 78 cases (12.7%) of single-column fractures, 420 cases (68.5%) of double-column fractures, and 115 cases (18.8%) of three-column fractures; the differences were significant among the three groups (P < 0.05). The ages were 39.8 years (range, 16–59 years), 46.6 years (range, 13–95 years), and 47.1 years (range, 15–95 years) for single-column, double-column and three-column fractures, respectively, showing significant difference among the three groups in total (P < 0.05). There was no significant difference in terms of gender between the three groups (P > 0.05). Inconsistency main occurred in patients with collapse type and mixed type of the intermediate column. In general, the intra-observer kappa coefficient was between 0.810 and 0.861 and the inter-observer kappa coefficient was between 0.830 and 0.876, with high consistency.

Among the intermediate column fractures, the most frequently encountered was the mixed type in 176 cases (28.7%), followed by the collapse type in 170 cases (27.7%) and the split type in 134 cases (21.9%), the dorsal type in 95 cases (15.5%), and the volar type in 28 cases (4.5%) was the least. Among the radial column fractures, 151 cases (35.9%) were metaphyseal type, 139 cases (33.1%) were articular surface type, and 130 cases (31.0%) were mixed type. Of the ulnar column fractures, 94 cases (81.7%) were styloid process type and 21 cases (18.3%) were metaphyseal type.

Among the 123 cases of volar and dorsal types, in 35 (28.5%) cases the diagnosis was missed by X-ray examination, but were confirmed by CT.

All patients were followed for 6 to 24 months, with an average of 12.2 months. To the last follow-up, the wrist joint function recovery was evaluated according to the Samiento modified Garland-Werley method [13]: excellent, 312 (51%); good, 195 (32%); fair, 92 (15%); and poor, 14 (2%). The excellent plus good rate of the single-column was 96.2%, significantly higher than that of double-column and three-column fractures (80.0% and 83.5%, respectively) (P < 0.05). See Table 1. All patients that had poor wrist function recovery were collapse or mixed type intermediate column fractures.
The intermediate column is not only the principal weight-bearing surface of the wrist joint, but also the hub of load transmission, while the radial and ulnar columns mainly stabilize and control the rotation of the wrist joint. Quite logically, therefore, among the GDP, the intermediate column fractures are always the most common and most obvious [14, 15]. The typical type of DP fracture is the collapse type of the intermediate column. Yang Y [11] and Chen M [12] believed that different types of DP fractures were related to the anatomical structure, the position of the wrist at the time of injury and the quality of the bone. Among the types of intermediate column fractures, the dorsal or volar type resulted from axial loads transmitted to the intermediate column when the wrist was either extended or flexed, generally resulting in an avulsion fracture. The split, collapse and mixed types occurred when the carpal joint was in neutral position at the time of load transfer. The normal distal radius exhibits a palmer tilt, i.e., the dorsal articular surface is higher than the volar side. Therefore, the dorsal articular surface of the lunate fossa is more susceptible to impingement and fracture during a fall or slip than the volar articular surface. In this study, the incidence of collapse and mixed type was 58.1%, significantly higher than that of other types, and the volar type was the least, all concordant with prior literature reports [10–12].

The incidence of double-column fractures was the highest (68.5%), whereas the incidence of single-column fractures was the lowest (12.7%), indicating that narrow-sense DP is rare while broad-sense DP is more common, again consistent with previous publications [7, 8, 16].

Single-column fractures were more common in young adults while two-column and three-column fractures were more common in middle-aged and elderly people. This was borne out with a significant difference in the age among the three groups in total (P < 0.05), which may be related to osteoporosis in the elderly, and fractures are more likely to spread to the radial and ulnar columns.

Because the volar and dorsal sides, radial and ulnar columns overlap on the AP and lateral plain films of X-ray, respectively, milder volar or dorsal type fractures of the intermediate column are easily missed by X-ray diagnosis alone. In the study, the missed diagnosis of X-ray plain film was 28.5%. Therefore, CT examination should be performed promptly in patients with milder volar or dorsal type fractures of the intermediate column.

Single-column fractures only occur in the intermediate column of the distal radius, and the radial column is intact, so it belongs to the B type (B1.3 or B4) on the AO classification; double-column and three-column fractures include intermediate column fractures associated with radial-column and/or ulnar column fractures, which are classified as type C (C1–C3) on the AO classification. Therefore, single-column fractures are relatively mild, associated with excellent or good functional recovery and rare subsequent traumatic wrist arthritis [17]. These outcomes are exemplified by a report from Zhou Z et al [6] of 11 cases of NDP treated surgically, with excellent and good outcomes in 7 and 2 cases, respectively, and only fair and poor outcomes in 1 case each; overall an excellent and good rate of 81.8%. Similarly, Xu L et al [18] reported 29 cases of single-column die-punch fractures, with excellent and good outcomes in 21 and 3 cases, respectively, and fair in 2 cases; an excellent plus good rate of 92.3%. Double- and three-column DP of the distal radius are more serious, especially the collapse and mixed types are more likely to cause traumatic wrist arthritis. Ye Y et al [8] reported that the excellent and good rate of functional recovery following double-column fractures ranged from 70%–86%, and traumatic wrist arthritis often occurred when improperly managed. In the present study, the excellent and good rate of the functional recovery of single-column fractures was 96.2%, which was statistically higher than that of double-column and three-column fractures (80.0% and 83.5%, respectively) (P < 0.05). All patients with poor outcomes by functional recovery analysis were of the collapse or mixed type that were caused by traumatic wrist arthritis due to poor fracture reduction. Therefore, meticulous attention to the treatment method of collapse or mixed type fractures is required.

**Conclusion**

GDP include single-, double- and three-column fractures. Different types of GDP have significant differences in terms of injury mechanism, incidence, age and prognosis. Classification by column and type of GDP reflects the features and has important reference value for clinical diagnosis and treatment.

**Abbreviations**

<table>
<thead>
<tr>
<th>Classification</th>
<th>Num</th>
<th>Incidence</th>
<th>Gender</th>
<th>Age (years)</th>
<th>Functional recovery</th>
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<td>Single-column</td>
<td>78</td>
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<td>39.8 ± 12.4</td>
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<td>420</td>
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<td>223/197</td>
<td>46.6 ± 19.2</td>
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<td>Three-column</td>
<td>115</td>
<td>18.8%</td>
<td>67/48</td>
<td>47.1 ± 17.2</td>
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<td>0.003</td>
<td>0.023</td>
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**Declarations**

**Conflict of interests**

The authors declare no competing interests.

**Funding**

None.

**Consent for publication**

The authors affirm that human research participants provided informed consent for publication of the images in Figures.

**Declaration of conflicting interests**

The authors declare no competing interests.

**Ethical approval declaration**

The study was reviewed and approved by the Institutional Review Board of Wuxi No. 9 People's Hospital Affiliated to Soochow University (No.LY-20200015), and performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

**Informed consent declaration**

Signed informed consent was obtained from all parents.

**Contributorship details**

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by Kai Zhao, Qudong Yin and Zhihai Zhang. The first draft of the manuscript was written by Kai Zhao and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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**References**


**Figures**

![Diagrammatic sketch of classification by column of GDP](image)

**Figure 1**

Diagrammatic sketch of classification by column of GDP: a: three column theory; b: classification by column of GDP
Figure 2

Volar type of the intermediate column fractures (recorded as A1). a, b:X-Ray films; c:CT reconstruction

Figure 3

Dorsal type of the intermediate column fractures (recorded as A2). a,b:X-Ray films; c:CT scan

Figure 4

Split type of the intermediate column fractures (recorded as A3). a,b:X-Ray films; c:CT scan
Figure 5
Collapse type of the intermediate column fractures (recorded as A4). a,b:X-Ray films; c: CT scan

Figure 6
Mixed type of the intermediate column fractures (recorded as A5). a,b:X-Ray films; c: CT Scan

Figure 7
Double-column DP with volar type of the intermediate column fractures and articular type of the radial column fractures (recorded as A1B1). a,b:X-Ray films; c: CT reconstruction

Figure 8
Double-column DP with collapse type of the intermediate column fractures and mixed type of the radial column fractures (recorded as A4B3). a,b:X-Ray films; c: CT scans and reconstruction
Figure 9

Three-column DP with collapse type of the intermediate column fractures, epiphysis type of the radial-column and styloid process type of the ulnar-column fractures (recorded as A4B2C1). a,b:X-Ray films:CT reconstruction